# BAN OF SMOKING ON INTERCONTINENTAL FLIGHTS - AN INTERVENTION STUDY ON INDOOR EXPOSURE IN AIRCRAFT, CLINICAL SIGNS AND SYMPTOMS FROM EYES AND NOSE

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## ABSTRACT

Relationship between passive smoking in intercontinental flights, cabin air quality (CAQ), symptoms, and clinical signs, were studied. All crew on four flights were invited to be investigated during flight (N=40). In addition, crew from six flights, staying at the crew hotel (N=48), were investigated at the hotel, after flight. Half of the flights were performed when smoking was allowed onboard, the others when smoking was prohibited. The participation rate was 81-98%. Nasal patency was measured with acoustic rhinometry. Eosinophilic cationic protein (ECP), myeloperoxidase (MPO), lysozyme and albumin were analysed in nasal lavage fluid. Hygienic measurements were performed in the aircraft, and at the hotel. Mean relative air humidity onboard was very low (4-7%). Ban of smoking resulted in a 95 % reduction of respirable suspended particles (RSP), and a 25-55% reduction of total VOC. Subjective air quality, eye and general symptoms, and total symptom score was reduced, tear film stability (BUT) was increased, and nasal patency onboard was decreased after ban of smoking. In conclusion, tobacco smoking in commercial aircraft increase in the exposure to RSP and other contaminants, increase symptoms, decrease tear film stability, and affect nasal patency. The study supports the view that smoking onboard should be avoided.

## INTRODUCTION

The future growth of aircraft transportation on global basis is estimated to be 5% per year [1], and worldwide nowadays more than 1,000 million people are transported by aircraft annually [2]. The cabin environment is characterised by a low relative air humidity, typically between 5-25%, [2-3]. There has been concern about ETS as a health hazard in aircraft during the last decade [4-9,2]. Many flight companies have prohibited smoking onboard, but for cultural or economical reasons, smoking is still allowed on some flights. Recently, objective methods to study environmental effects on the upper airways and eyes have been applied, including

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acoustic rhinometry [10], nasal lavage to study inflammation in the nasal mucosa, and measurements of objective signs from the eyes, e g tear film stability [11-12]. To our knowledge, these methods have yet not been applied in aviation medicine. The aim of the investigation was to study the influence of environmental tobacco smoke in civil aircraft crew, with respect to subjective air quality, symptoms, and clinical signs from the nose and eyes.

## MATERIAL

Airline crews on four flights between Scandinavia and Japan (N=40) were invited to participate, in a medical investigation during flight. Two flights were performed when smoking was allowed onboard, in end of august 1997. The other two flights were performed in September 1997; two weeks after ban of smoking. Current symptoms during flight were gathered by a questionnaire. In total, 39 (98%) answered the medical questionnaire, and 37 (93%) participated in the medical examinations. In addition, crew from six flights staying at the crew hotel (N=48) were invited to a post-flight investigation at the crew hotel in central Tokyo, 39 (81%) participated. The subjects were interviewed by a physician about allergy and other diseases, medication, smoking habits, and were investigated clinically. There were no asthmatics in the crew during the smoking flights, but two asthmatics during non-smoke smoking flights. Since the numerical differences in asthmatics between the groups could have biased the results of a small study, the statistical analysis was restricted to non-asthmatics.

Acoustic rhinometry (Rhin 2000, S.R. Electronics, Denmark; wideband noise; continuously transmitted) was performed [10]. The measurements were made under standardised forms (sitting), after five minutes rest, and prior to the lavage of the nose were measured from 0 to 22 mm (MCA1) and from 23 to 54 mm (MCA2), from the nasal opening. Also the volumes of the nasal cavity on the right and left side were measured from 0 to 22 mm (VOL1) and from 23 to 54 mm (VOL2). The mean values were calculated from three subsequent measurements on each side of the nose, and data on nasal dimensions in the present study are presented as the sum of the values from the right and the left side.

Lavage of the nasal mucosa was made by a previously described method [11] with a 20-ml plastic syringe attached to a nose olive. The subjects were standing, with their head flexed ca 30° forward. The room tempered (20-22°C) sterile 0.9% saline solution was introduced into the nasal cavity. Each nostril was lavaged with five ml solution that was flushed back and forth five times via the syringe, at an interval of a few seconds. The fluid was transferred into a 10-ml polypropylene centrifuge tube. They were kept on ice and within 300 minutes, the solution was centrifuged at 800 g for five minutes. The supernatant was recentrifuged at 1400 g for five minutes, and immediately frozen to -20°C. Lysozyme was analysed by means of radioimmunoassay [13]. The concentrations of ECP and MPO were measured by means of a double antibody radioimmunoassay method (Pharmacia Diagnostics AB, Uppsala, Sweden) [14-15]. Albumin was measured by rate nephelometry on an Array protein system (Beckman Instruments Inc).

The same type of major intercontinental aircraft, with a total number of 180 seats, was used on all flights. It has a ventilation system normally providing approximately 50% fresh air and 50% recirculated air to the passenger cabin. Normally, the air exchange rate should be about 7 turnover per hour of fresh air in the cabin, or about 10 litres of outdoor air per passenger and second. Occasionally, the pilot can shut off the recirculation fans for shorter moments,

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resulting in a 100% fresh air supply and an air exchange rate of about 12-15 turnovers per hour in the cabin. The air exchange rate on flight deck is about 60 turnovers per hour. Ozone is removed by passing the fresh air through a catalytic ozone converter. The cabin air circulation system utilise a pre-filter for larger particles, a high efficiency particulate air filter (HEPA) capturing particles of 0.3 µm and larger, and a charcoal filter to remove volatile compounds. The air-conditioning system does not contain any air humidification devices.

In-flight measurements were performed simultaneously with the medical investigation onboard, and in the room at the crew hotel where the post-flight medical investigations were performed. In-flight temperature, air humidity, dust, and carbon dioxide ($CO_2$) were recorded with a SWEMA logger 15 (SWEMA AB, Sweden), sampling one minute average values. Respirable dust were measured by a direct reading instrument based on light scattering (Sibata P-5H2, Sibata Scientific Technology Ltd, Japan), and $CO_2$ by a direct reading infrared spectrometer (Rieken RI-411A, Rieken Keini, Japan). Airborne microorganisms were sampled on 25 mm nucleopore filters with a pore seize of 0.4 µm and a sampling rate of 1.5 L/min for 4 hours. The total concentration of airborne moulds and bacteria, respectively, was determined by the CAMNEA method [16]. Nitrogen dioxide was sampled with a diffusion sampler and analysed by a spectrophotometric method [17]. A diffusion coefficient of 0.154 $cm^2/s$ was used in the calculations, as proposed by the manufacturer (Passam Ag, Zurich, Switzerland). Ozone was measured with another diffusion sampler from IVL, Sweden [18]. To achieve sufficient detection limits, the sampling time was expanded to 16 hours, during two flights on the same sampler.

Formaldehyde was measured with glass fibre filters impregnated with 2,4-dinitro-phenylhydrazine [19], the air sampling rate being 0.2 L/min during four hours, and analysed by liquid chromatography. Volatile organic compounds (VOC) were measured with on charcoal sorbent tube (Anasorb 747; SKC 226-81) with the same sampling time and airflow rate as for formaldehyde. The charcoal tubes were desorbed with 1 mL of carbon disulphide, and analysed for specific compounds by a Hewlett Packard 5890 gas chromatograph with a mass selective detector (HP 5970) [20]. Total VOC was analysed by a gas chromatograph (Hewlett Packard 5880A) with a non-polar column, and flame ionisation detector (FID). The total concentration of VOC below n-dodecane (C12) was calculated, assuming the same response rate as for n-decane (decane-equivalents).

## RESULT

The number of eye symptoms and general symptoms, as well as the total symptom score was significantly lower ($p<0.05$), and the perception of the cabin air quality was improved after ban of smoking ($p<0.05$). The differences were most pronounced for general symptoms. Before ban of smoking, 35% of the crew reported at least one general symptom (headache, fatigue, nausea, and sensation of catching a cold). After ban of smoking, 0% reported general symptoms ($p=0.005$ by Fisher's exact test). Tear film stability (BUT) during flight was increased after ban of smoking ($P<0.05$). Rhinometric measurements on-board showed greater posterior nasal cross-sectional area (MCA2) during smoke flights, as compared to non-smoke conditions ($P<0.05$), but no differences for other nasal dimensions (Table 1). Post-flight measurements of tear film stability (BUT), nasal patency, and biomarkers in nasal lavage showed no significant difference at the hotel, when comparing smoking and non smoking flights.

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Table 1 Symptoms and signs onboard in non-asthmatic airline crew, before and after ban of smoking.

| Type of symptoms/signs | Before ban of smoking (N=20) M (SD) | After ban of smoking (N=19) M (SD) |
|---|---|---|
| BUT during flight (seconds) | 10(8.7) | 25(31)* |
| MCA1 during flight ($cm^2$) | 1.33(0.19) | 1.35(0.37) |
| VOL1 during flight ($cm^3$) | 3.88(0.56) | 4.13(0.83) |
| MCA2 during flight ($cm^2$) | 1.52(0.45) | 1.22(0.37)* |
| VOL2 during flight ($cm^3$) | 8.98(2.56) | 8.81(2.59) |
| Perceived air quality (0-100%) | 36±21 | 52±26* |
| Number of eye symptoms (0-6) | 1.90(1.94) | 0.68(0.95)* |
| Number of general symptoms (0-4) | 0.65(1.14) | 0(0)* |
| Total number of symptoms (0-19) | 3.90(4.04) | 1.42(1.57)* |

*P<0.05

The average relative air humidity in aft galley was 7%, bot during smoke flights and non-smoke flights, and 4% in forward galley. Carbon dioxide concentrations were below the recommended Swedish ventilation standard of 1000 ppm in 99.6% of all measurements. The average concentration of respirable suspendible particles (RSP) in aft galley was 66 $\mu g/m^3$, with a maximum value of 253 µg/m3 during smoke conditions. The corresponding values during non-smoking conditions were 3 $\mu g/m^3$ in aft galley, with a maximum value of 7 $\mu g/m^3$. These differences were highly statistically significant ($p<0.001$). Respirable dust in the forward galley was measured only during non-smoke conditions, the average concentration was 4 $\mu g/m^3$, with a maximum of 12 $\mu g/m^3$.

The concentration of viable moulds and bacteria was low, (< 100 $cfu/m^3$), and no detectable total concentrations of moulds or bacteria were found by the CAMNEA method (<10 000 $organisms/m^3$). The average ozone concentration was 14 $\mu g/m^3$ in aft galley, and 33 $\mu g/m^3$ in forward galley. The concentrations of $NO_2$ was below the detection limit (<10 $\mu g/m^3$) both in aft and forward galley. The concentration of formaldehyde in the cabin was below the detection limit (<5 $\mu g/m^3$) during all flight, irrespectively of smoking or non-smoking conditions. Mean concentrations of total VOC was 620 $\mu g/m^3$ in aft galley during smoking flights, 470 $\mu g/m^3$ during non-smoke flights, and 350 $\mu g/m^3$ at the hotel.

Average room temperature in the investigation room at the hotel was 23.4 °C in August 1997 and 23.9 µC in September 1997. Average relative air humidity in the room was 65% both in August and September. The average concentration was 12 $\mu g/m^3$ for RSP, 5 $\mu g/m^3$ for formaldehyde, and 5 $\mu g/m^3$ for ozone. The concentration of $NO_2$ was below the detection limit (<10 µg/m3). No detectable air concentrations of viable moulds were found (< 100 $cfu/m^3$), and the concentration of viable bacteria was low (110 $cfu/m^3$). No detectable concentration of total mould were found by the CAMNEA method (<10 000 $organisms/m^3$). The total concentration of bacteria was 12 000 $organisms/m^3$.

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## DISCUSSION

The relative air humidity was very low onboard, both in aft and forward galley (3-8 %). Other studies have also found low relative air humidity in aircraft, typically 5-49% [21,2-3], but not as low as our values, which were performed during cruising at high altitude (33-37 000 feet), near the north pole with extremely low outdoor humidity. Despite an efficient air filtration system and separation between smokers and non-smokers, smoking onboard caused a 22 fold increase of respirable suspendable particles (RSP) in the aft galley. Earlier studies, focusing on the passengers, exposure to ETS, have found similar results; a 5-20 fold increase of RSP at passenger's seats during smoking flight, as compared to non-smoking flights [4,6,8]. Besides the high levels of RSD during smoking conditions, and the low relative air humidity, other exposure measurements showed low or normal values. In conclusion, tobacco smoking in commercial aircraft causes a drastic increase in the exposure to respirable suspendible particles. The exposure to ETS may increase the prevalence of irritative symptoms, particularly ocular and general symptoms, impair the perception of cabin air quality, and decrease tear film stability among aircraft crew. The results support the view that despite a high air exchange rate and efficient air filtration, smoking in commercial aircraft leads to a significant pollution, and should be avoided. It also implicates that measurement of tear film stability and acoustic rhinometry, and detection of biomarkers of inflammation in nasal lavage fluid can be applied to study nasal and ocular reactions to the cabin environment.

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